Traffic Management Advisor Multi Center (TMA-MC) Operational Concept Description

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Prepared for

NASA Ames Research Center
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Preface

This report was developed from the referenced documents in order to conform to the required contents of an Operational Concept Description (OCD) as jointly defined by National Aeronautics and Space Administration (NASA) and the Federal Aviation Administration (FAA) Free Flight Project Office. The majority of the descriptive material has been taken verbatim from the referenced documents (and noted with square brackets around reference) available at the time of publication. Modifications have been made to add sections not in previous concept descriptions, to improve readability, and to reflect the most currently available information.

This approach to the development of this document was taken in order to remain faithful to the efforts that are presently being undertaken by the NASA Advanced Air Traffic Technologies (AATT) Project Office, the Tool Developers and the associated NASA AATT contractors.

This document was prepared by Titan Systems Corporation, 700 Technology Park Drive Billerica, MA under Contract Number NAS2-98005. It represents CDRL #3.b.2 of Research Task Order 72 “AATT Operational Concept Description for Air Traffic Management Year 2002 Update”.

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1. Scope

1.1 Identification

This document is the Operational Concept Description (OCD) for the Traffic Management Advisor – Multi-Center (TMA-MC) decision support tool (DST).

1.2 System Overview

Purpose

[p 1-1 Reference 1]* Multi-Center Traffic Management Advisor is an extension of the current Traffic Management Advisor Single-Center (TMA-SC) tool into a multi-facility environment. The purpose of TMA-MC is to assist Traffic Management Coordinators (TMCs) in planning and managing streams of traffic into selected airspace, as well as into selected Terminal Radar Approach Control (TRACON) facilities that receive traffic from two or more en route centers. The focus of TMA-MC research will be on the Northeast corridor, particularly the improvement of arrival flows into Philadelphia International Airport (PHL), thereby increasing operational efficiency at this airport and identifying the requirements for TMA-MC at the New York airports. However, as described in subsequent section, TMA-MC has potential applicability to other Centers and TRACONS.

General Nature of the System

[p 2-1 Reference 1] TMA-MC builds on NASA Ames Research Center (ARC) Center-TRACON Automation System (CTAS) TMA and its single-center arrival management orientation to provide a tool that enables efficient management and metering of traffic in complex airspace (e.g., the Northeast). A complex airspace is defined as one in which multiple facilities (multiple Centers and/or multiple TRACONs) with interdependent traffic flows are responsible for delivering traffic to a congested airport.

History of System Development, Operation, and Maintenance

[p 1-1Reference 1] During the summer of 1998, both government and industry representatives identified the need to maintain the momentum of the Free Flight Phase 1 (FFP1) program, which includes the CTAS TMA-SC as one of it primary components. At that time, there was not an agreed-upon plan for further deployment of FFP1 tools or any new capabilities mature enough for implementation during the post-FFP1 period. Therefore, the RTCA Free Flight Steering Committee formed a government/industry-working group responsible for defining those next steps. This group, called the RTCA 2003 - 2005 Capabilities Working Group, developed a set of recommendations that delineated those next steps. Based on the FAA response and other deliberations, the "Government/Industry Operational Concept for the Evolution of Free Flight, Addendum 1 Free Flight Phase 1" (Reference 2) evolved to the "National Airspace System Concept of Operations" (Reference 3), "Addendum 4 Free Flight Phase 2" (FFP2) (Reference 4),

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* References in square brackets [ ] at the beginning of a section indicates that the section following was extracted verbatim from the referenced document.

and “National Airspace System Concept of Operations and Vision for the Future of Aviation” (Reference 5). The working group identified specific problem areas where there are no mature capabilities but where research might provide the needed solutions available for a 2003-2005 implementation. One of the identified areas of research which is expected to come to fruition in the 2003-2005 timeframe is the TMA-MC. As one of the anticipated new capabilities in the 2003-2005 timeframe, TMA-MC has been designated as a component of the FFP2 program being executed by the FAA’s Free Flight Program Office (AOZ).

The NASA-developed prototype TMA-SC DST is currently in daily use at the FAA's Fort Worth Center (ZFW) and aids the FAA's operational personnel in planning and controlling air traffic into the Dallas-Fort Worth International Airport (DFW).

Use of the TMA-SC DST has contributed to a substantial increase in arrival rates at DFW and has resulted in favorable comments from both FAA operational personnel at ZFW and the airlines that operate at DFW. As part of the FAA's FFP1 program, a nationally deployable version of the TMA-SC at ZFW has been deployed to the following Air Route Traffic Control Centers (ARTCCs): Minneapolis (ZMP), Denver (ZDV), Los Angeles (ZLA), Atlanta (ZTL), Miami (ZMA), and Oakland (ZOA). The TMA-SC benefits summary (Reference 6) shows increases in airport acceptance rates (AARs) and actual acceptance and operations rates during arrival peaks at ZMP, a reduction of delays for internal departures at ZLA, and anecdotal evidence that ZTL and ZMA are using TMA-SC to evaluate miles-in-trail (MIT) alternatives to improve arrival flow management.

The TMA-MC research, as a part of the FAA's FFP2 program, will investigate the modifications needed to enhance the planning capabilities of TMA-SC for traffic management decision makers in multiple facilities to improve the metering of aircraft to a congested resource (airport or airspace). It is envisioned that the research to enhance TMA-SC will result in the development of an effective tool for addressing traffic management challenges not only in the busy Northeast corridor, but throughout the entire National Airspace System (NAS).

TMA-MC is in a preliminary development phase and as of 3rd quarter of FY 2002 was at Technology Readiness Level (TRL) 4, defined as involving high-fidelity human in the loop testing in the laboratory and field, and requiring an update of the concept of use.

Project Sponsor, Acquirer, User, Developer, and Maintenance Organizations

The NASA AATT Project is the sponsor of TMA-MC; the developer is the Terminal Area Air Traffic Management Research Branch at NASA ARC; TMA-MC is being developed for delivery to the FAA building upon TMA-SC. The FAA will be the acquirer, user, and maintenance organization. TMA-MC research and development will be coordinated with the FAA through the TMA-MC Research Transition Plan (Reference 1).

Current and Planned Operating Sites

The focus of TMA-MC research is on multi-center environments that have more than one center feeding a single TRACON. PHL, a busy hub in the Northeast Corridor, will be the initial implementation site for TMA-MC. Eventually other locations in the country that have more than one center feeding a single TRACON may be included.

The TMA-MC tool development sites will include the following facilities involved in the PHL arrival process:

- New York Center (ZNY)
- Washington Center (ZDC)
- Philadelphia Terminal Radar Approach Control (PHL TRACON)
- Boston Center (ZBW)
- Cleveland Center (ZOB)

Additional sites in the Northeast Corridor and the NAS are to be determined.

Other Relevant Documents

Documents that are relevant to the TMA-MC concept are referenced in Section 2.

1.3 Document Overview

The AATT NAS OCD is being created to document current research and to provide concept guidance for the AATT project. However, it is designed with the understanding that each project element would require a separate detailed description of a subset or domain in the NAS in which a particular deficiency is addressed. This TMA-MC OCD is intended to provide guidance for TMA-MC system requirements development, to address how TMA-MC fits into airspace arrival planning operations and the overall NAS, and to provide a means to help transfer this technology to the FAA.

This document is organized according to a format based on the IEEE J-STD-16-1995 standard (Reference 7). Descriptions of the OCD sections follow.

Section 1. Scope: This section contains a full identification of the system to which this OCD applies. It briefly states the purpose of the system; describes the general nature of the system; summarizes the history of system development, operation, and maintenance; identifies the project sponsor, acquirer, user, developer, and maintenance organizations; identifies current and planned operating sites; summarizes the purpose and contents of this document; describes any security or privacy protection considerations associated with its use; and lists other relevant documents.

Section 2. Referenced Documents: This section lists the number, title, version, date, and source of all documents referenced in this document.

Section 3. Current System/Situation: This section describes the background, mission, objectives, and scope of the current system/situation including applicable operational policies and constraints and a description of the current system/situation. The description includes, as applicable:

- The operational environment and its characteristics.
- Major system components and the interconnections between these components.
- Interfaces to external systems or procedures.
- Capabilities/functions of the current system.

- Charts and accompanying descriptions depicting input, output, data flow, and manual and automated processes.
- Performance characteristics, such as speed, throughput, volume, and frequency.
- Quality attributes, such as reliability, maintainability, availability, flexibility, portability, usability, and efficiency.
- Provisions for safety, security, privacy protection, and continuity of operations in emergencies.

In addition, a description of the types of users or personnel involved in the current system is included. This section also provides an overview of the support strategy for the current system.

Section 4. Justification for and Nature of Change: This section describes new or modified aspects of user needs, threats, missions, objectives, environments, interfaces, personnel, or other factors that require a new or modified system. It summarizes deficiencies or limitations in the current system that make it unable to respond to these factors. All new or modified capabilities/functions, processes, interfaces, or other changes needed to respond to these factors are summarized in this section. In addition, this section identifies priorities among the needed changes; changes considered but not included; the rationale for not including them; and, any assumptions and constraints applicable to the identified changes.

Section 5. Concept for a New or Modified System: This section describes the background, mission or objectives, and scope of the new or modified system and any applicable operational policies and constraints and a description of the new or modified system. The description includes, as applicable:

- The operational environment and its characteristics.
- Major system components and the interconnections between these components.
- Interfaces to external systems or procedures.
- Capabilities/functions of the new or modified system.
- Charts and accompanying descriptions depicting input, output, data flow, and manual and automated processes.
- Performance characteristics, such as speed, throughput, volume, and frequency.
- Quality attributes, such as reliability, maintainability, availability, flexibility, portability, usability, and efficiency.
- Provisions for safety, security, privacy protection, and continuity of operations in emergencies.

In addition, a description of the types of users or personnel involved in the new or modified system is included. This section also provides an overview of the support strategy for the new or modified system.

Section 6. Operational Scenarios: This section describes one or more operational scenarios that illustrate the role of the new or modified system, its interaction with users, its interface to other systems, and all states or modes identified for the system.

Section 7. Summary of Impacts: This section describes anticipated operational, organizational, and development impacts on the user, acquirer, developer, and maintenance organizations.

Section 8: Analysis of the Proposed System: This section provides a qualitative and quantitative summary of the advantages, disadvantages, and/or limitations of the new or modified system. Major system alternatives, the tradeoffs among them, and rationale for the decisions reached are also provided.

Section 9: Notes: This section contains general information that will aid the reader's understanding of this OCD. It includes an alphabetical listing of all acronyms and abbreviations and their meanings as used in this document, and a list of terms and definitions.

2. Referenced Documents

1. Free Flight Phase 2/NASA Ames Research Center, *Research Transition Plan for Developing the Multi-Center Traffic Management Advisor (TMA-MC*), Version 5.0, May 2002.
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3. RTCA, *National Airspace System Concept of Operations*, December 2000.
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5. RTCA, *National Airspace System Concept of Operations and Vision for the Future of Aviation,* December 2002.
6. FAA, *Free Flight Phase 1 December 2001, Benefits Summary*, http://ffp1.faa.gov/approach/approach_ben_met.asp.
7. *IEEE J-STD-16-1995 Standard for Operational Concept Descriptions*
8. FAA, *Order 7210.3S, Facility Operation and Administration*, August 8, 2002.
9. FAA, *Order 7110.65N, Air Traffic Control*, August 8, 2002.
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11. Anon, *Draft Traffic Management Advisor- Multi Center (TMA-MC) Concept of Use,* Version 3.1, NASA Ames Research Center, October 2002.
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13. Hoang, T., Farley, T., Foster, J., and Davis, T., *The Multi-Center TMA System Architecture and Its Impact on Inter-Facility Collaboration,* AIAA 2002-5813*,* AIAA Aircraft Technology, Integration and Operations 2002 Technical Conference, October 2002.
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15. Wang, J.J., *Initial Life-Cycle Cost/Benefit Assessment of Multi-Center Traffic Management Advisor,* bd Systems Incorporated, August 30, 2002.
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18. Metron, Inc., *Multi-Facility TMA: Fully Dependent TMA Analysis*. Conducted in Support of NASA Advanced Air Transportation Technologies (AATT) under Contract NAS2-98001, Research Task Order 32, December, 2000.
19. Wang, Jianzhong; Barrington, Craig; and Datta, Koushik: Life Cycle Cost-Benefit Assessment of TMA, pFAST, EDP, SMA, SMS, aFAST, and McTMA. Contract Report, Advanced Air Transportation Technologies Project, NASA Ames Research Center, Moffett Field, CA, Sept. 2001.
20. Sawyer, B. M.; Smith, J. L.; Mackey, W. L., Sr.; Reuss, L. M.: Investigation of Implementation Sites for Multi-center Traffic Management Advisor (McTMA) AATT

Decision Support Tool – Final Report. Science Application International Corporation (SAIC), 600 Maryland Avenue, SW, Suite 760E, Washington, DC 20024, Dec. 2000.
21. FAA: Free Flight Phase 2, Free Flight Research Program Plan (Draft), Version 2.0. Free Flight Program Office, Federal Aviation Administration, Washington, D.C., Oct. 2001
22. Titan System Corporation, *General Description Multi-Center Traffic Management Advisor (McTMA),* Prepared under RTO 62, January 31, 2002.

3. Current System/Situation

3.1 Background, Objectives, and Scope

There are a number of locations around the US for which controllers from multiple en route Centers coordinate arrivals into a single TRACON. TMA-MC is a decision support tool that is designed to help coordinate these arrivals and support the en route controllers in sequencing and spacing arrivals to the TRACON. A particularly challenging operational problem is coordinating arrivals into PHL airport and it is the subject of initial TMA-MC research and testing. PHL and its surrounding airspace is unique in the nature and complexity of its airspace. Facilities involved in the PHL arrival process include ZNY, ZDC, ZBW, ZOB, and PHL TRACON, as well as the airport Tower. Because of this early emphasis on PHL, this OCD has a substantial amount of detail about how TMA-MC might be employed to support PHL operations. However TMA-MC has applicability to other TRACONS and Centers around the country and additional details will be generated for these locations as plans for expanded deployment of TMA-MC are developed.

3.2 Operational Policies and Constraints

The operational policies and constraints relevant to the present traffic management system are contained in References 8 and 9:

- *FAA Order 7210.3S, Facility Operation and Administration*; February 21, 2002; Part 2, Air Route Traffic control Centers; Part 3, Terminal Air Traffic Control Facilities; and Part 5 Traffic Management System are particularly relevant to this OCD.
- *FAA Order 7110.65N, Air Traffic Control*; February 21, 2002; Chapter 2, General Control; Chapter 3, Air Traffic Control – Terminal; and Chapter 11 Traffic Management Procedures also contains material that describes the operations of the existing surface traffic control system.

3.3 Description of Current System or Situation

[[Reference 10. The description is current as of 2001.]

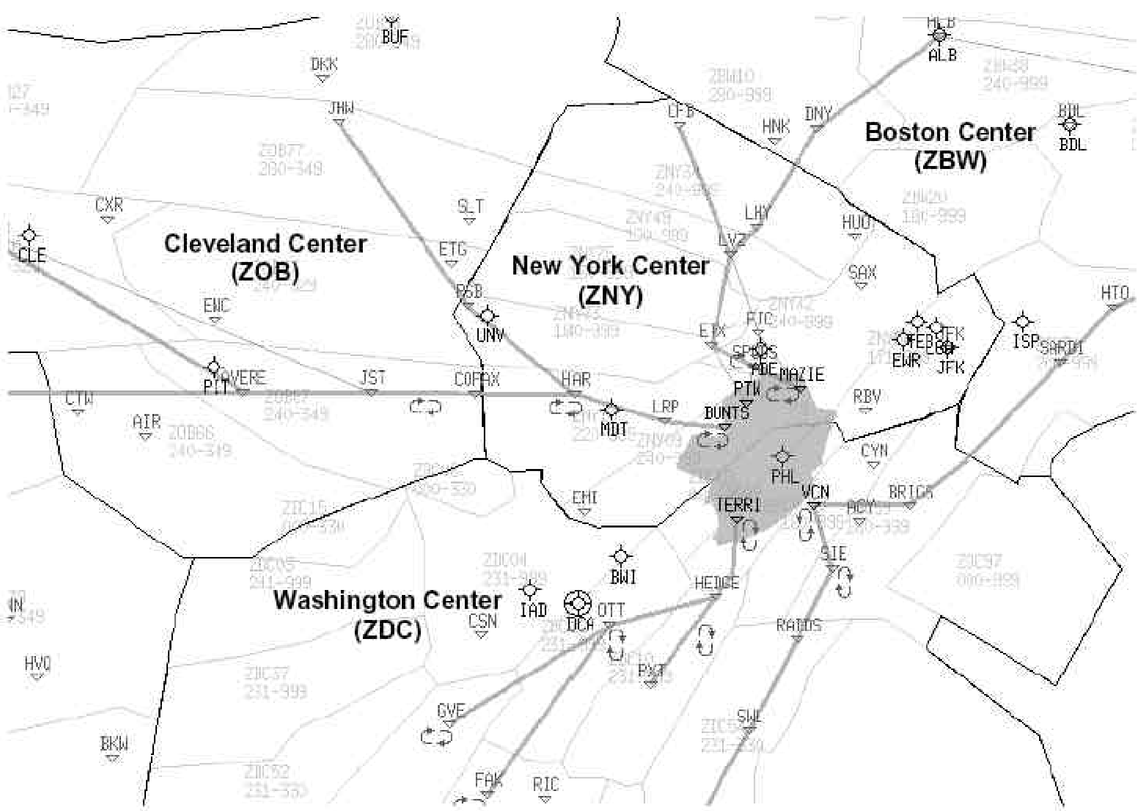
<u>Philadelphia Traffic Management</u>

Philadelphia International Airport is the sixth most delay-prone airport in the US. As a hub airport for USAirways, PHL typically experiences seven arrival rushes per day, each containing a significant mix of turbojet and turboprop traffic. To contend with these rushes, PHL traffic managers typically impose MIT restrictions on each arrival flow. When in-trail restrictions prove inadequate, they resort to airborne holding at one or more arrival fix(es). Although less efficient than a time-based metering (TBM) strategy, these measures are effective in maintaining safe separation and manageable controller workload levels, and the measures are implemented with great skill, developed from years of daily practice. Both of these measures occur routinely at PHL, even under the most favorable weather conditions.

Philadelphia Terminal Area Layout

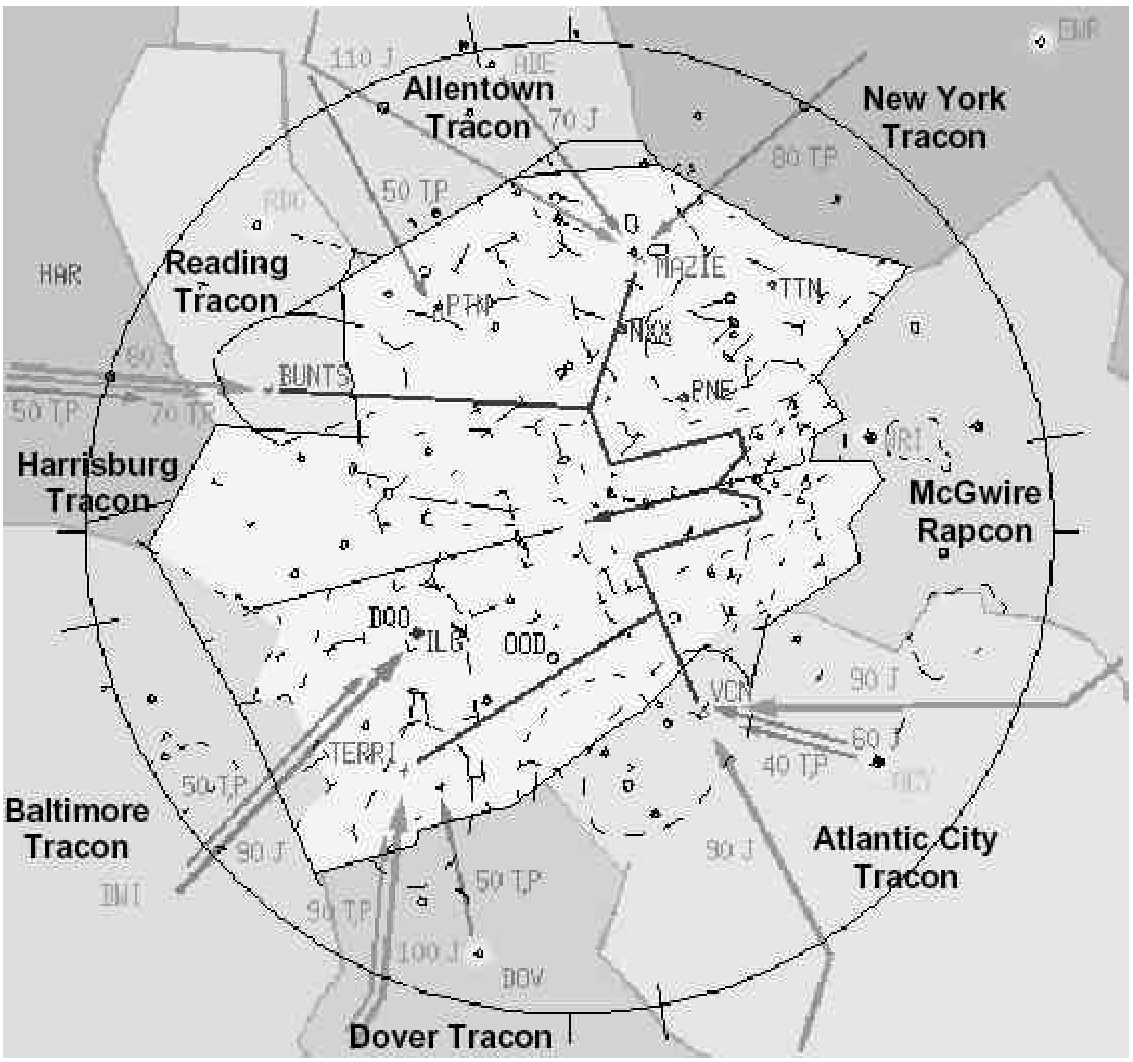
Traffic flow management problems at PHL are compounded by virtue of the cartography of the region. The Philadelphia TRACON straddles the boundary between New York Center and Washington Center (see Figure 1). Approximately 60% of arrival aircraft flow into the TRACON from these two en route Centers. The remaining 40% of arrivals enter the TRACON from six adjacent approach control facilities (see Figure 2). Clockwise from the north, they are: Allentown, New York, Atlantic City, Dover, Baltimore, and Reading. While most of these aircraft are destined for PHL, a significant proportion are bound for satellite airports (including Northeast Philadelphia (PNE), Trenton (TTN), Wilmington (ILG) and Navy Willow Grove (NXX)), and these satellite arrivals enter PHL TRACON through the same five arrival gates as the PHL arrivals. Roughly half of all PHL arrivals come from the west over BUNTS. These are primarily turbojet aircraft from the Midwest and West Coast. Another third of PHL traffic, a mix of jets and props, arrives from the south and east over TERRI and Cedar Lake (VCN), respectively. TERRI captures traffic from Atlanta, Memphis and the Gulf states; Cedar Lake is the entry point for flights originating on the Atlantic Coast, from Boston to Miami. MAZIE is the entry point for jets from upstate New York and parts of New England; prop traffic from those areas is routed over Pottstown (PTW).

Figure 1. PHL TRACON (Shaded Area) and Adjacent Airspace



Cleveland Center and Boston Center lie within 130 nautical miles of PHL. These upstream facilities play an important role in the arrival process. The close proximity of these facilities to PHL also means that upsets in the PHL arrival process quickly ripple back upstream to affect operations in these Centers. Furthermore, chronic congestion in this region increases the interaction and dependency of the traffic streams. As a result, upsets in the PHL flows frequently impact flows to other destinations, setting off a domino effect of additional delay and workload throughout the region. Because all of these facilities have a role and an interest in the PHL arrival process, formulating and executing a coordinated arrival plan among all of them poses a significant challenge, but one with potentially far-reaching benefits.

Figure 2. PHL TRACON and Surrounding TRACONS (Shaded)



Arrival Centers

PHL TRACON is delivered arrival aircraft by two centers: New York Center and Washington Center. New York Center is commonly characterized as a “big TRACON.”

A large percentage of its traffic is in transition to/from major airports in the New York metro area (e.g., LaGuardia (LGA), Newark (EWR), Kennedy (JFK)). The airspace is comprised of narrow corridors which funnel aircraft in and out of the metro area. Its small sectors, high traffic density, and diverse traffic mix of aircraft in transition make ZNY a highly complex operation. ZNY owns the BUNTS, PTW, and MAZIE arrival fixes, and therefore has a role in controlling PHL arrivals from the west and north. In addition, ZNY has a role in descending Cedar Lake arrivals from New England, accepting flights from ZBW and passing them off to ZDC (jets) or Atlantic City approach (props) prior to Cedar Lake.

Washington Center serves predominantly north–south traffic flows headed to/from the Washington or New York metro areas. Major ZDC airports include Dulles International (IAD), Baltimore/Washington International (BWI), Reagan Washington National (DCA), and Raleigh/Durham (RDU). ZDC also handles significant volume associated with Atlanta–Hartsfield (ATL) and Charlotte (CLT). Because of the significant workload associated with the flows in and out of New York and Washington, PHL traffic is not a major part of their focus. ZDC owns the TERRI and VCN arrival fixes, and therefore has a role in controlling PHL arrivals from the south and southeast In addition, ZDC merges converging streams of arrival traffic from the Atlantic Northeast and the Atlantic Southeast at Cedar Lake.

First-Tier Centers

Cleveland Center and Boston Center are responsible for the initial descent of aircraft on arrival to Philadelphia from the west and north, respectively. Cleveland Center handles more aircraft per day than any ARTCC in the NAS. Most of these flights are long-haul flights from major hub airports such as San Francisco, Denver, St. Louis, and Chicago–O'Hare (eastbound) and Boston, Philadelphia and the New York airports (westbound). A significant volume of traffic originates or terminates at one of its three major internal airports: Cleveland– Hopkins (CLE), Detroit–Wayne (DTW), or Pittsburgh (PIT). Cleveland Center is responsible for organizing the predominant stream of traffic into PHL, the BUNTS arrival. Cleveland sets up this flow for New York Center, handing off aircraft at the ZOB–ZNY boundary at 25,000 feet, approximately 125 nm from PHL. Although fairly homogeneous (mostly jets on a dedicated PHL arrival airway), this flow is made complex by heavy crossing traffic in/out of the Washington metro airports and Cincinnati (CVG), and by departure/arrival traffic associated with Pittsburgh, Columbus (CMH) and Dayton (DAY). Also, Cleveland Center is responsible for a secondary flow (approximately four aircraft per rush) into New York Center (and BUNTS) from upstate New York (Rochester (ROC), Buffalo (BUF)) and Toronto (YYZ). Although the secondary flow is light, it is a critical contributor to workload and delay (see "Workload" below). These primary and secondary flows must be merged in a small sector in ZNY. To reduce the odds of two aircraft arriving in a tie over the ZNY boundary, heavy in-trail restrictions are levied on the secondary flow. This is a natural application for TBM, which could eliminate these restrictions.

Boston Center handles a diverse mix of operations. In addition to major airline service in and out of the primary airports (Boston (BOS), Providence (PVD), Bradley (BDL), and Manchester (MHT)), it also acts as a gateway facility for international flights over the Atlantic. A large proportion of its traffic is turboprop/commuter aircraft bound for New York airports. Boston Center handles two arrival flows destined for PHL. The first collects flights from southern New England (e.g., Boston, Providence, Bradley, Islip (ISP)) which are routed along the Atlantic Coast into New York Center. This flow is complicated, because it is mixed with another flow of traffic in the opposite direction sharing the same airway. One flow is southbound to destinations along the Atlantic Coast; the other is a major northbound artery into New York and New England. Thus, there is traffic in transition in both directions along the same airway. The second PHL arrival flow collects flights from northern New England (e.g., Burlington (BTV), Manchester), Canada (e.g., Montreal (YUL), Ottawa (YOW)) and western New York (e.g., Syracuse (SYR), Albany (ALB)), all of which are brought over upstate New York to New York Center.

3.4 Users or Involved Personnel

The involved personnel include:

- Air Traffic Control Systems Command Center (ATCSCC) Traffic Management Specialists (TMSs)
- En Route TMCs
- En Route radar controllers
- Terminal area TMCs

Table 1. Users/Involved Personnel for Current Operations

Users or Involved Personnel	Current Operations
Traffic Management Specialist at ATSCSS	✓
Air Traffic Control Supervisor (ATCS)	✓
Supervisory Traffic Management Coordinator-in-Charge (STMCIC)	✓
Operations Supervisors (OS)	✓
Traffic Management Coordinator (TMC)	✓
En Route Radar Position – R controller	✓
En Route Radar Associate (RA) – D controller	✓
En Route Radar Coordinator (RC)	✓
En Route Radar Flight Data (FD) Position	✓
En Route Non Radar (NR) Position	✓
Terminal Traffic Management Coordinator	✓
Terminal Radar Position – R controller	
Terminal Radar Associate (RA) – D controller	
Terminal Radar Coordinator (RC)	
Terminal Radar Flight Data (FD) Position	
Terminal Non Radar (NR) Position	
Tower Local Controller (LC)	
Tower Ground Controller (GC)	
Tower Associate	

Tower Traffic Management Coordinator	✓
Tower Flight Data Position	
Tower Clearance Delivery Position	
Flight Service Station Specialist (FSSS)	
Airline or Aircraft Flight Operations Center (AOC)	
Pilot or Flight Crew (FC)	

3.5 Support Strategy

To be determined

4. Justification for and Nature of Change

4.1 Justification for Change

[p2-2 Reference1] The NAS is currently experiencing operational inefficiencies when demand for selected airspace and airports exceeds capacity. Sometimes, these inefficiencies are the unintended byproduct of locally optimal but uncoordinated actions taken by separate facilities that feed traffic to the congested resource. Lacking the infrastructure and information to develop a coordinated multi-facility response to prevent over-demand, traffic managers must resort to reactive, uncoordinated MIT restrictions which often result in unpredictable holding and/or ground delays (i.e., schedule unpredictability). These inefficiencies are especially prevalent in the busy Northeast corridor facilities: ZOB, ZDC, ZNY, ZBW, New York TRACON (N90), and Philadelphia Tower.

The FAA's desire to meet customer operational efficiency requirements, particularly at PHL, has prompted the investigation of procedural and technical means to promote multi-facility coordination/collaboration in order to more effectively manage the flow of traffic to selected airspace and terminal facilities, while maintaining a high level of safety. The TMA-MC research effort is envisioned to play a key role in helping to alleviate the operational inefficiencies described above.

One specific problem faced in the Northeast corridor is the management of PHL arrival traffic. Philadelphia TRACON lies on the boundary of ZDC and ZNY. To regulate traffic into PHL, MIT restrictions are imposed by PHL on ZDC and ZNY (and its adjacent TRACONs). These restrictions are sometimes inadequate to address the overall congestion problem. ZNY, for example, may have to resort to additional MIT restrictions to their first tier centers (especially ZOB, and sometimes ZBW) or to airborne holding (sometimes without prior notice) as their means of flow management. Holding, especially when unexpected, usually results in the inefficient utilization of the airport's runway capacity and excessive controller workload. In addition, PHL arrivals are affected by traffic management actions taken to regulate the flow of traffic between N90 and the Washington, D.C. metropolitan airports (especially IAD arrivals), which constitutes the majority of traffic in the Northeast corridor. Since PHL traffic is significantly constrained by N90 traffic patterns (East Coast Plan airspace and route structures) and Northeast congestion (e.g., choke-points), the TMA-MC research may help to determine how to mitigate some of the problems associated with the N90 and Northeast congestion. A specific issue for TMA-MC research, which will be focusing on PHL, will be to understand what changes, if any, need to be made to TMA-MC for it to be effective for New York airports.

Flow management currently operates in a "reactive" mode for PHL airspace. In the multi-ARTCC environment of PHL, TMCs at multiple ARTCCs are involved in flow management. Each ARTCC TMC has only part of the arrival picture; the TRACON TMC is the first person in the arrival flow management progression to have the full arrival picture. Because numerous "short-hop" flights are an unpredictable element of an arrival rush, flow management is further complicated, leaving the TMC without the ability to accurately predict arrival demand.

At the PHL TRACON, aircraft are allowed to flow into the TRACON until it is overloaded. At that point, the PHL TMC shuts off the flow from the ARTCCs. This can cause a disruptive process known as no-notice holding which occurs when a downstream facility is at or over capacity and refuses to accept any more hand-offs from the upstream or feeding facility. It is very disruptive to the facilities and creates a very tense and antagonistic working environment. Once the situation in the TRACON is under control, the flow is resumed from the ARTCCs. However, the timing of the decision to resume the flow does not often result in an immediate resumption of efficient operations due to aircraft not all being in the perfect position when the system is ready to resume normal operations after holding has been instituted. This reactive mode of traffic management creates significant inefficiencies in the arrival flow.

[p 30 Reference 15] Based on the results of a SAIC study of implementation sites for TMA-MC (Reference 19), previously bd chose (Reference 20) six candidate sites for TMA-MC. The six candidate sites were PHL (Philadelphia), CLT (Charlotte), MCO (Orlando), TPA (Tampa), IAD (Washington – Dulles), and BWI (Baltimore –Washington). PHL is NASA's TMA-MC demonstration site, and NASA's TMA-MC developers confirmed that the other 5 sites are also likely TMA-MC sites. However, strong indications from various sources have suggested that additional sites need to be included in the list.

According to the FAA's Free Flight Research Program Plan (Reference 21), "TMA-MC will be installed and operating in the Northeast corridor providing a metering capability into Philadelphia by 2005. If the cost/benefit data continues to show favorable results, adaptation of this system for metering into a New York airport could commence". NASA's TMA-MC developers also believe there is little doubt that New York TRACON (N90) should be the next choice after Philadelphia, with Boston TRACON (A90) right after it. Thus, New York and Boston were added to the original list of 6 TMA-MC sites.

The research and development philosophy for TMA-MC, according to NASA's TMA-MC developers, is to ultimately replace TMA-SC at all applicable TMA-SC sites to provide more benefits. For example, if TMA-MC could replace TMA-SC at Los Angeles, it would help tremendously to coordinate incoming traffic from the Oakland ARTCC – another TMA-SC FFP1 site. Moreover, the cost for doing so would be minimal because the hardware and infrastructure already exist. Similarly, Kansas City possesses the same qualification and so is a candidate TMA-MC site.

Furthermore, NASA's TMA-MC developers strongly recommended, based on their internal studies, the inclusion of Chicago and Detroit into the list of TMA-MC site selection candidates. With the addition of these 4 sites - SCT (Los Angeles), T75 (Kansas City), C90 (Chicago), and D21 (Detroit), the total number of potential TMA-MC sites grew to 12.

4.2 Description of Needed Changes

[p 2-3 Reference 1] The TMA-MC research effort should help to achieve increased operational efficiency through several means. First, it provides an opportunity to enhance collaboration using decision support tool technology to address the complex challenges associated with coordinating arrival streams originating from more than one en route center that are destined for a single airport. Second, it facilitates exploration of TBM as a potential solution to alleviating bottlenecks in the complex Northeast corridor, both at en route sectors and arrival airports. Third, the results of the TMA-MC research should aid the airspace redesign efforts in the Northeast corridor of the United States. This will be particularly significant for operations at PHL, as well as at the New York airports. Moreover, not only will the Eastern Region benefit from this research, but other locations in the NAS with similar airspace/center-airport configurations will benefit from the knowledge gained in the investigation of new traffic management procedures

In an effort to research the application of TMA-SC to a complex multi-facility environment and to potentially provide some benefit to operations in the Northeast, the TMA-MC research will be conducted in two evolutionary increments of functionality. The emphasis of the first increment, referred to as Multi-Facility Collaboration, is to utilize the TMA-MC schedule information via the current TMA-SC user interfaces to facilitate common traffic flow visualization, coordination, and collaboration across multiple facilities involved in managing traffic to busy terminal areas. During this increment, research efforts also will be focused toward understanding how best to transition to TBM (as one of the procedures available to solve a congestion problem) in this complex environment. Through this common flow visualization and TMA-MC's accurate prediction capability, traffic managers will collaboratively determine restrictions (e.g., ground delays, MITs, and meter fix or boundary crossing times) that meet their negotiated arrival rates. One of the goals of the first phase of TMA-MC research is to help the participating traffic managers gain confidence in the underlying TMA-SC time-based scheduling (modified for the multi-facility environment) that will be the basis for their collaboration.

The second TMA-MC research increment, referred to as Collaboration and Metering, will allow traffic managers in all target facilities to collaboratively meter traffic flows across (selected) sector boundaries or through meter fixes (all or a subset) using TBM. It is expected that the transition to TBM (using scheduled times instead of MIT restrictions to control flows) will begin after TMA-MC is used to help the traffic managers collaborate on MIT restrictions and regulate the congested traffic (Increment 1). After gaining experience with using TMA-MC scheduling technology to coordinate MIT restrictions across multiple facilities (Increment 1), the TMCs will transition to mixing MIT restrictions for one set of flows with (time-based) schedule restrictions for another set of flows. Scheduled times of arrival (STAs) for each metered aircraft will be displayed to the appropriate sector controllers. Finally, TMCs will use STAs for all the flows to PHL. The flow visualization functionalities utilized in the first increment will remain intact, and will likely include enhancements derived from the research conducted during that increment.

4.3 Priorities Among the Changes

All changes are integral to the design of TMA-MC, and as such are of equal priority.

4.4 Changes Considered But Not Included

NASA has explored and partially developed a Spacing Tool capability that assists controllers with conflict-free planning of efficient spacing-conformance actions. The

Spacing Tool would leverage 4D trajectory prediction capability to predict the future spacing/merge of flights, and introduce the use of trial planning techniques, integrated with conflict probe, to pre-plan spacing actions. Similarly, the FAA is exploring a Problem Analysis and Resolution and Ranking (PARR) tool that is aimed at providing sector controllers with a tool to more effectively achieve spacing-conformance. However, both approaches are aids to implementing current day MIT restrictions. Instead of duplicating that capability, TMA-MC introduces a time-based approach that enables controller conformance through metering advisories (which include the metering times themselves and delay countdown). In addition to metering advisories, TMA-MC offers the advantage of also assisting TMCs in the optimal formulation and coordination of flow restrictions.

4.5 Assumptions and Constraints

[p 5 Reference 11] In addition to providing common visualization graphical collaboration tools to all participating facilities for arrival flow management, TMA-MC is designed to facilitate the implementation of TBM.

- For this concept of use, TBM is assumed to be a frequently used method of arrival flow management for the facilities using TMA-MC. TBM is the arrival flow management process where en route sector controllers deliver arrival aircraft to the TRACON (and other boundaries or fixes) at times that are calculated by TMA-MC and which are displayed to the controllers, as opposed to delivering arrival aircraft using fixed MIT separations. However, TBM may be used in conjunction with MIT restrictions to deliver aircraft to the TRACON, and there may be occasions when MIT restrictions are preferred.
- PHL is the lead facility for defining PHL's current and future runway configurations, and its AAR.
- All facilities (PHL, ZNY, ZDC, ZOB, and ZBW) have TMA-MC workstations that display the same set of load graphs and timelines which are oriented on PHL (showing its airport, runways, and primary airport metering fixes) and which are updated continuously as radar updates, or TMC inputs, are received. In this timeframe, the ATCSCC *MAY* have access to the same set of displays.
- PHL is the lead facility for initiating a telephone conference with the other participating facilities (ZNY, ZDC, ZOB, and ZBW) to decide whether to use TBM (exclusively or in combination with MITs) at the en route sectors feeding arrival traffic to PHL. The TMCs in the participating facilities use the same common TMA-MC graphical information (primarily load graphs and timelines) to help them make their metering decision.
- If the facilities decide to meter, they agree on the following details:
    - When to start and end metering
    - Where, in which sectors, to implement TBM
    - How to apply metering, such as via sector controller metering lists and departure delays for internal airport departures.

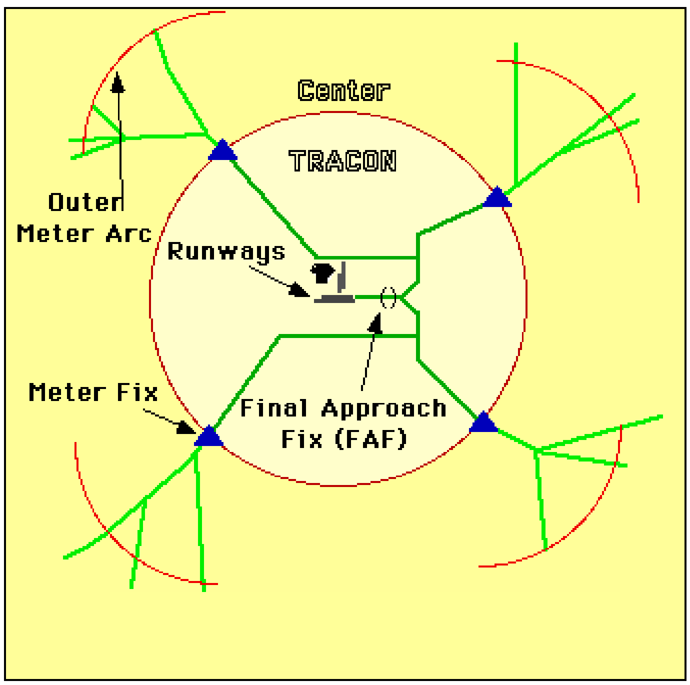
- If the ATCSCC did not participate in the metering decision telecon, they are informed of the decision to meter.

5. Concept for a New or Modified System

5.1 Background, Objectives, and Scope

[Reference 12] The Center air traffic controllers and TMCs control arriving aircraft that enter the Center from an adjacent Center or depart from feeder airports within the Center. On the basis of the current and future traffic flow, the TMC creates a plan to deliver the aircraft, safely separated, to the TRACON at a rate that fully subscribes, but does not exceed, the capacity of the TRACON and destination airports. The TMC's plan consists of sequences and scheduled times of arrival (STAs) at the meter fix, published points that lie on the Center-TRACON boundary. The Center air traffic controllers issue clearances to the aircraft in Center so that they cross the meter fixes at the STAs specified in the TMC's plan. Near the TRACON, the Center controllers hand the aircraft off to the TRACON air traffic controllers. Figure 3 illustrates the TMA-SC geometry for single center operations.

Figure 3. TMA Single-Center Geometry



The TMA-SC assists, but does not replace, the Center TMCs and air traffic controllers in several ways. TMA-SC increases situational awareness through its graphical displays and alerts. TMA-SC also generates statistics and reports about the traffic flow. In addition, TMA-SC computes the undelayed estimated time of arrival (ETA) to the outer meter arc, meter fix, final approach fix and runway threshold for each aircraft. Furthermore, TMA computes the sequences and scheduled times of arrival (STAs) to the outer meter arc, meter fix, final approach fix, and runway threshold for each aircraft to meet the sequencing and scheduling constraints entered by the TMC. The TMA-SC also assigns each aircraft to a runway to optimize the STAs. Although the TMA-SC computes the STAs and runway assignments for each aircraft in Center, the Final

Approach Spacing Tool (FAST) may overrule these STAs and runway assignments when the aircraft enters the TRACON airspace. TMA-SC continually updates its results at a speed comparable to the live radar update rate in response to changing events and controller inputs.

An important feature of TMA-SC is its ability to sequence and schedule aircraft to the outer fix, meter fix, final approach fix, and runway threshold in such a way as to maximize airport and TRACON capacity without compromising safety. In addition, TMA-SC will assign the aircraft to runways to optimize the schedule. All of this activity takes place while the aircraft is in the Center's airspace (approximately 40 to 200 miles from the arrival airport). Moreover, scheduling of some aircraft takes place before the aircraft have even entered the Center's airspace as long as that aircraft's flight plan is received by CTAS. TMA-SC will schedule aircraft based on the aircraft's flight plan information that may be received as much as 90 minutes before the aircraft enters the Center's airspace. TMA-SC will update these sequences, schedules, and runway assignments constantly to adapt to changes in the traffic situation, changes in the environment, or in response to inputs by the TMCs.

TMA-SC provides a number graphical features that improve situational awareness while accepting inputs from the controllers and TMCs. The graphical features that improve situational awareness include timelines, load graphs, planview displays, sequence lists, traffic count overlays, aircraft watch windows, rush alerts, data degradation alerts, and other text overlays. The TMCs and controllers can interact with TMA through control panels, buttons, sliders, pop-up menus as well as clicking and dragging various graphical entities on the displays. These graphical features are displayed by the Timeline Graphical User Interface (TGUI) and the Planview Graphical User Interface (PGUI).

5.2 Operational Policies and Constraints

The operational policies and constraints relevant to the present traffic management system are contained in References 8 and 9. These operational policies and constraints will have to be modified to accommodate TMA-MC operations that are described in the following sections.

- *FAA Order 7210.3S, Facility Operation and Administration*; February 21, 2002; Part 2, Air Route Traffic control Centers; Part 3, Terminal Air Traffic Control Facilities; and Part 5 Traffic Management System are particularly relevant to this OCD.
- *FAA Order 7110.65N, Air Traffic Control*; February 21, 2002; Chapter 2, General Control; Chapter 3, Air Traffic Control – Terminal; and Chapter 11 Traffic Management Procedures also contains material that describes the operations of the existing surface traffic control system.

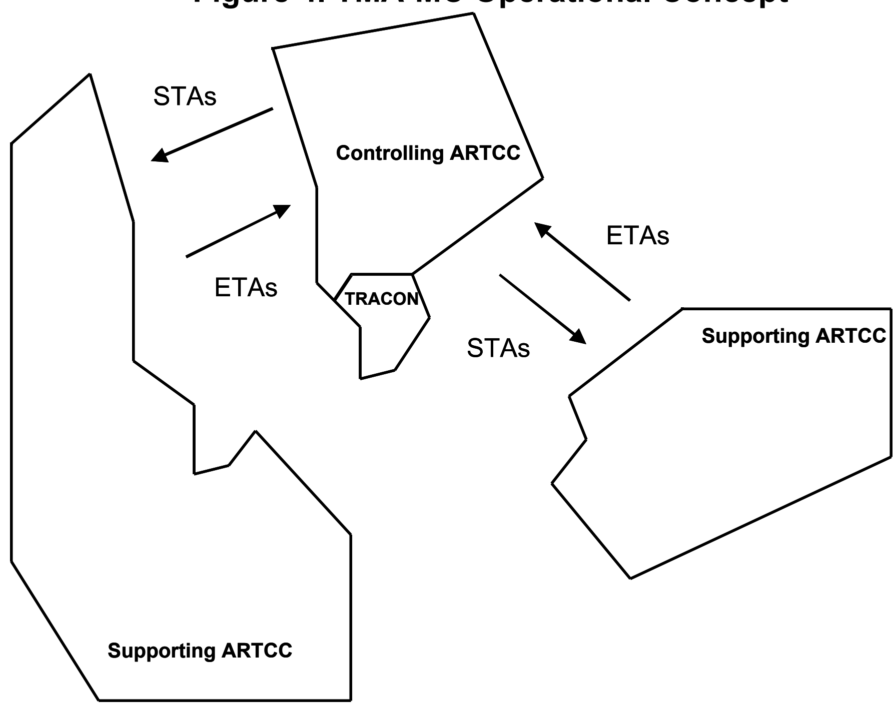
5.3 Description of the New or Modified System

[p 4 Reference 22] TMA-MC is the extension of TMA-SC to regions where multi-center coordination is required. Ideally, TMA-MC and TMA-SC would be identical, except for the need to coordinate TMA-generated planning information between the facilities.

Therefore, TMA-MC will operate in the same way as TMA-SC with minimal restrictions added for acceptable joint facility operation.

[p 8 Reference 22] One of the ARTCCs involved in the flow management process is assigned the responsibility of entering scheduling parameters into the TMA-MC system. It is expected that the ARTCC TMU whose host computer is associated with the TRACON approach control will make these entries. In general, every TRACON has one and only one controlling ARTCC from a TMA-MC perspective. Any ARTCCs that are computing ETAs for aircraft bound to a TRACON that the ARTCC does not control would send the ETA information to the TMA-MC system in the controlling ARTCC. The planning function in the controlling ARTCC TMA-MC would create the integrated schedule for all flights arriving at the primary airport and send the STAs back to the contributing CTAS systems (See Figure 4).

Figure 4. TMA-MC Operational Concept



The parameters entered by the controlling ARTCC TMC appear on all TMA displays, including those at the supporting ARTCCs, the TRACON and the ATCSCC. The availability of a TMA display at the ATCSCC would enhance the collaborative planning between ATC facilities. In addition to the scheduling parameters, all TMA displays show the schedule that has been developed by the controlling ARTCC. This schedule assigns airport and arrival fix crossing times to flights to make efficient use of airport arrival capacity and to equitably distribute delay among flights.

After the schedule has been modified by the controlling ARTCC TMC to manage flow and workload, the scheduled arrival fix crossing times are broadcast from the controlling ARTCC TMA to the sector controller displays. The implementation of TBM by the controller in the TMA-MC case follows the same procedures as the TMA-SC case. Controllers give speed and descent clearances and use vectors to control flights to cross the arrival fix at the assigned time. If necessary, controllers can swap the assigned slots for flights that have the same approach speed profiles. The complexity and congestion of the TMA-MC airspace may cause unavoidable delay. This may, in turn, cause some flights to miss their assigned arrival fix crossing time. The frequency of occurrence of this phenomenon and the severity of impact on the overall arrival situation will be the subject of further analysis. As the TBM plan is being implemented, TMCs at the TRACON monitor performance and evaluate the need for re-planning of the arrival schedule.

TMA-MC is essentially the process of coordination among separate TMA tools operating in the controlling and supporting ARTCCs that feed a common TRACON. Figure 5 illustrates the functional flow of TMA-MC operating in the controlling ARTCC and depicts the functional interfaces with the supporting ARTCC and external data sources, TMA-MC functions and interfaces. The input sources, appearing in double boxes, are shown in the figure. The sub-functions are shown in the central portion of the figure enclosed in dashed lines.

TMA-MC Architecture

[p 3 Reference 13] The functionality of the TMA-MC system mirrors that of the TMA-SC system. Both systems predict arrival demand, generate arrival sequences and schedules, and calculate aircraft delay absorption values. Controllers then impose delay mechanisms upon the aircraft so airport capacity is not exceeded. Like the TMA-SC model, the TMA-MC model requires installation of the software at each ARTCC facility.

Whereas TMA-SC was designed to be a self-sufficient independent system, the advantages of the TMA-MC system become apparent when it is connected into a network. The TMA-MC system extends the aircraft prediction and controllability horizon into upstream air traffic control facilities. Cooperation and data sharing are key components of the TMA-MC architecture. A network of TMA-MC systems can be used to share data and aid inter-facility collaboration. In addition, the TMA-MC system at a particular ARTCC behaves and functions just like a TMA-SC system when it is installed as a “stand alone” system. TMA-MC will either be installed as a new system or it will replace an existing TMA-SC system at an ARTCC.

Following are two figures that further illustrate the architecture of the TMA-MC system. Figure 6 shows the data sharing architecture among the TMA-MC systems and their respective Hosts to capture and provide a regional view of the traffic. Figure 7 shows the software modules that make up the TMA-MC system. Subsequent sections provide details of the elements depicted in the figures.

TMA-MC Network

The TMA-MC network is a homogeneous network; mixing TMA-SC and TMA-MC systems on the Wide Area Network (WAN) is not possible. The network requires all participating Centers to have a TMA-MC system installed. Sites running TMA-SC would have to upgrade their software to TMA-MC before connecting to the TMA-MC network. Further, the infrastructure of the stand-alone TMA-SC system is not designed to communicate with other TMA-SC systems.

Figure 5. TMA-MC Functional Flow

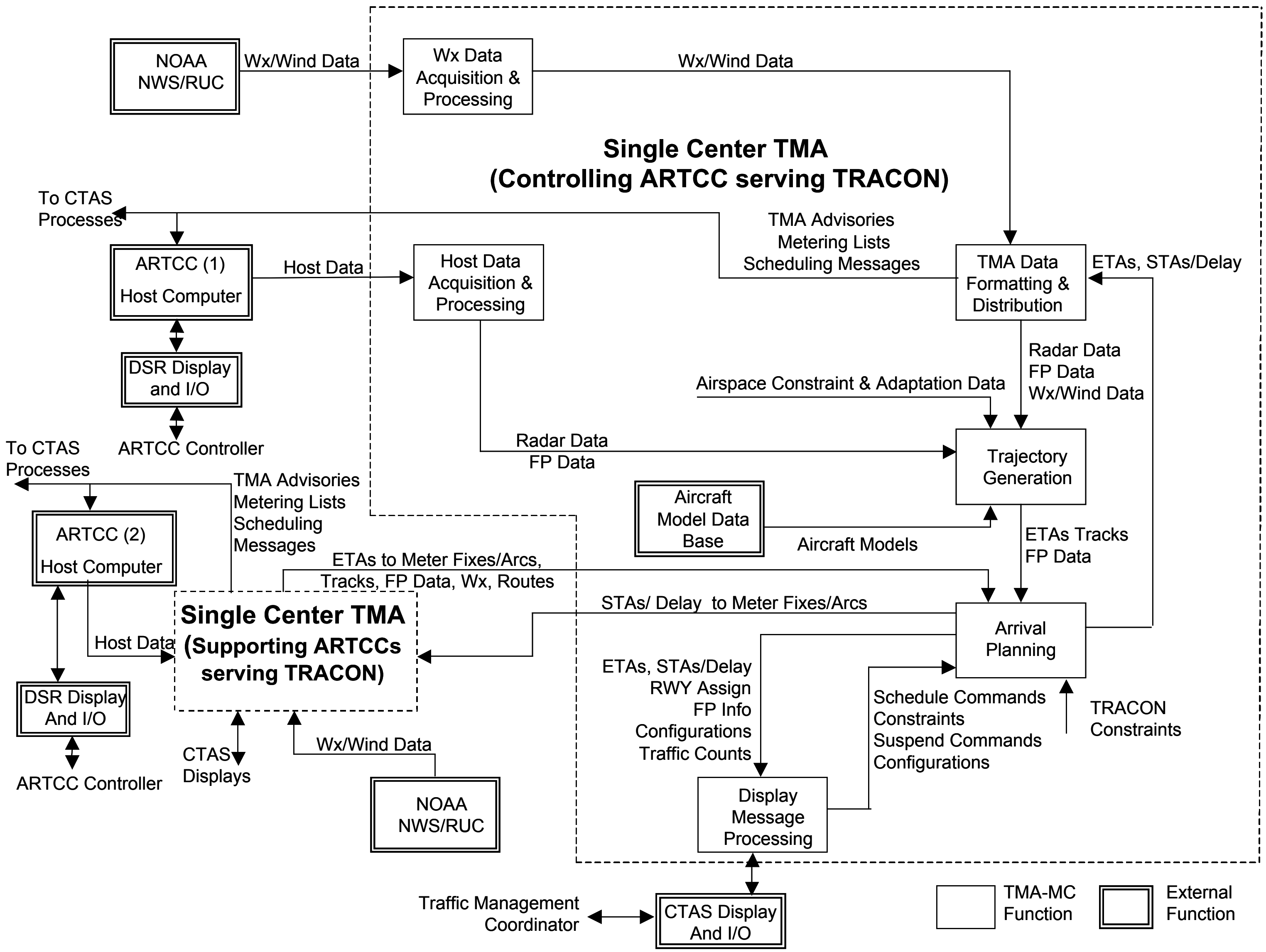


Figure 6. TMA-MC Wide-Area Network Topology

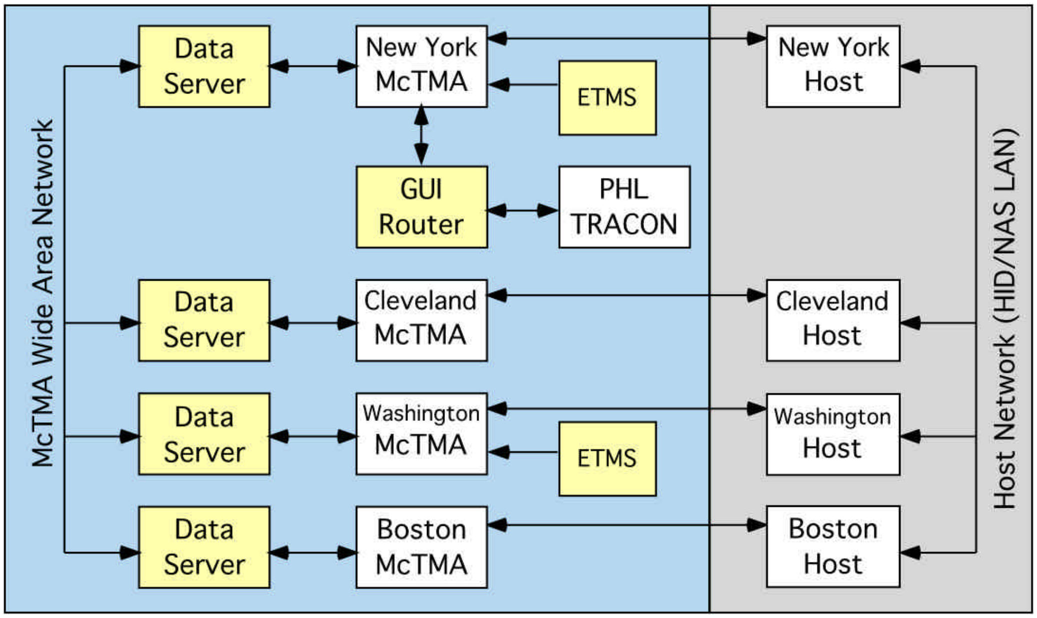
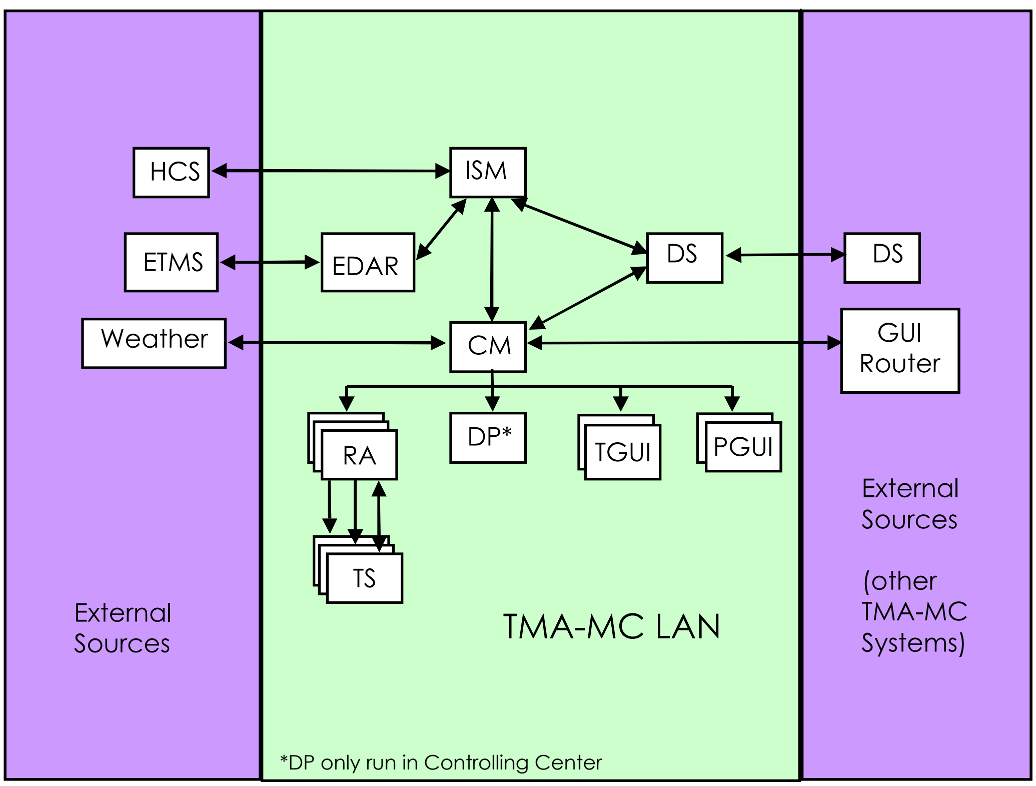


Figure 7. TMA-MC Software Modules



The nomenclature describing the functionality of each TMA-MC system and how it contributes to network data sharing is described below. A Center can be defined as a controlling, an arrival, or an adjacent facility, or any combination thereof. Because there is one TMA-MC system per Center, a controlling Center owns the controlling system.

The controlling Center controls the Dynamic Planner (DP) scheduler generating all STAs to the arrival airport. The schedules generated by the controlling Center are made available to the arrival and adjacent systems. The situation is unique for the PHL airport because two Centers each own a portion of the arrival gates to the PHL TRACON. ZNY has ownership of the PHL TRACON and all flight-plan processing eventually gets routed to the ZNY Host. For the rest of this description, ZNY is the controlling Center.

The arrival Center controls the meter fix that feeds aircraft into the TRACON and contains the destination airport within its borders. The arrival Centers are New York controlling the BUNTS, PTW, and MAZIE meter fixes, and Washington controlling the TERRI and VCN meter fixes. These facilities provide the controlling Center with interim demand forecast using data collected from their local Host computer.

An adjacent Center feeds aircraft into the arrival and controlling Center. It provides the arrival Center with an extended forecast of the traffic demand. Because it does not own an arrival gate, the adjacent facility generates partial-trajectory ETAs and forwards the data to the controlling Center, which returns STAs. In this scenario, Cleveland and Boston are adjacent Centers to New York.

Figure 6 shows the four TMA-MC Centers, ZNY, ZOB, ZDC, and ZBW on the WAN. The PHL TRACON uses the graphical user interface (GUI) router to extract display information that it needs. The requests are routed through the Communications Manager (CM) and data server (DS) processor at ZNY (Figure 7). These processes are described more fully below. The data servers from other sites then supply the ZNY data server with the information that it requested. On the Host Computer System (HCS) side, each Host shares data over the HID/NAS LAN (HNL) network.

The architecture of the MTA-MC network is straightforward and builds upon the TMA-SC setup. Each TMA-MC system communicates with the local Host computer and shares that data with other TMA-MC systems within the architecture that parallels that of the Host's network. The two-way data communication connection between the TMA-MC system and its local Host provides a direct link between the two networks. The two-way communication allows TMA-MC to receive data such as flight plans, tracks, and other messaging data from the Host. It also allows the Host to receive scheduling, sequence, and delay data from TMA-MC. The PHL TRACON is also shown as being part of the TMA-MC network although there is no corresponding Host connection. This illustrates the system's capability to distribute shared data to other facilities enabling traffic flow decisions to be made with information not normally available. Each TMA-MC system can receive data from other sources besides the Host, including weather data and Enhanced Traffic Management System (ETMS) data. In addition, the controlling Center, New York, can indirectly collect data from the TRACON Computer (Automated Radar Terminal System (ARTS)) via the ETMS interface.

Inter-facility Collaboration and Coordination

[p 9 Reference 13] The TMA-MC features described here complement each other in encouraging the TMU and TMC to actively participate in the planning and execution of the flow management game plan. In summary, TMA-MC gathers traffic data from adjacent Centers, and the TRACON to provide a complete picture of demand, shares the data through a common flow visualization display, and provides advisories (time-based schedules) and possible solutions to the impending traffic demand.

The algorithms being developed for TMA-MC try to mimic the current operational procedures. The coordination of sector handoffs and the arrangement of in-trail traffic require close interactions between the sectors. The smaller sectors collaborate across boundary lines to solve the bigger traffic control picture. Better coordination between sectors helps set up an arrival flow that is more workable by the receiving sector. The upstream sectors typically have more airspace allowing them to set up a better flow and to absorb a larger percentage of the delays. In essence, the smaller sectors are transforming themselves into a larger airspace to control traffic. The TMA-MC architecture utilizes this coordination scheme and expands it beyond the sector airspace by including the Centers themselves, via the Data Server, to provide inter-facility collaboration.

One fundamental benefit that TMA-MC offers, even without the scheduling capability, is the ability to predict the arrival demand on a regional level. Other systems, such as ETMS, provide regional information based on current track data or aircraft situation, but do not provide the prediction capability and accuracy that TMA-MC offers.

The following topics in this section illustrate other areas where TMA-MC can provide additional assistance to the TMCs. TMA-MC can be used to schedule release times for departure from an adjacent airport destined for PHL. Because of its accurate prediction capability, TMA-MC can eventually remove the disruptive process known as no-notice holding, thereby providing a smooth delivery of traffic into the TRACON.

It should be noted that there is an on-going separate study led by MITRE's Center for Advanced Aviation Systems Development (CAASD) that addresses the operational aspects of collaboration and coordination between the Centers and the PHL TRACON. This research will be the basis for future integration and implementation of the TMA-MC system at other sites.

Scheduling of Call-For-Release Aircraft

The level of control that TMA-MC offers will help refine some of the air traffic management methods existing today. Because TMA-MC can provide accurate STAs, the facilities can collaborate to find the best time to release an aircraft from an airport in a neighboring facility so that it can merge into an open slot in the overhead PHL arrival stream. Possible candidate airports include Pittsburgh, Cincinnati, and Boston Logan.

The current call-for-release method begins when the tower TMC initiates a phone call to the TMC at the Center. The tower indicates that it would like to release a PHL bound aircraft, say USA1217, at a specific time. The Center TMC draws on past experience to determine if the Center has a slot to accommodate USA1217 in the PHL arrival stream. The Center TMC estimates the climb-out time for the aircraft to join the overhead stream and selects a slot. The TMC has the flexibility to advance or delay the departure time and relays that time to the tower TMC. This is a tedious process that may or may not work well, and requires some knowledgeable guesswork that varies with each coordinator's skill.

The process also has a significant shortcoming because it involves making the judgment based on a single Center's limited view of the traffic. A call-for-release made to benefit one Center now may cause a cascade of problems downstream. This in turn may cause more problems upstream when the hand-offs to the downstream facility are rejected due to overcapacity.

One TMA-MC operational concept dealing with call-for-release aircraft has the Center TMC selecting the slot that the arrival is going to occupy in the arrival stream. Using the TGUI interface, the TMC drags-and-drops the aircraft call sign into the slot and a release strip is automatically printed out at the tower. The scheduler determines a departure time that is conflict-free at the arrival runway, reserves a slot for the call-for-release aircraft in the arrival stream and a corresponding slot at the runway. If necessary, appropriate delays will be applied to satisfy the airport acceptance rate (AAR). Ideally, the decision to make the assignment of the call-for-release aircraft should come from the Center that owns the departure airport. This keeps the authoritative structure in line with the current operational procedures.

No-Notice Holding

The no-notice holding situation occurs when a downstream facility is at or over capacity and refuses to accept any more hand-offs from the upstream or feeding facility. This occurs with some frequency and without notice between the Northeast Centers. It is very disruptive to the facilities and creates a very tense and antagonistic working environment. When the downstream facility "shuts its gate", the upstream facility must do whatever it can to control the aircraft it currently owns. This typically means giving the order to fly the holding pattern. The sector takes further protective action by passing upstream more restrictive constraints (i.e., larger in–trail separation).

Getting mired in a no-notice situation is undesirable and unpleasant. This circumstance also hampers the controller's ability to strategize a plan that provides a smooth and steady flow of traffic after the expiration of the no-notice period. When the receiving facility is again able to accept handoffs, the resumption of the traffic flow is often very inefficient. Aircraft from the upstream sector may not be at the best speeds, headings, or altitudes to immediately resume their flight path over the metering point or arrival gate. During the recovery period, the upstream sectors may not have enough aircraft in the queue to deliver a nominal load thereby forfeiting landing slots. This creates inefficiencies at both the sector and airport because of under-utilization.

Through the TGUI or PGUI displays (via the GUI router), the regional demand and delay profiles are made available to all facilities. Each Center can detect the impending demand problem in advance and devise plans to correct the problem, thus avoiding the disruptive domino effect when a gate is suddenly closed.

If holding is still required, however, regional demand and delay profiles on the TGUI and PGUI provide information to execute a systematic recovery. The upstream facility will be able to more efficiently queue up and resume delivery of traffic to the downstream facility.

This reduces the inefficiencies that occur when resuming from a holding situation. The queue is always being updated in TMA-MC because aircraft states and demand predictions are constantly being updated.

Other Applications

Rerouting of aircraft from one gate to another gate is an optional procedure that is available to each Center. However, it is very labor-intensive and seldom exercised. With TMA-MC, this method of traffic management can be exercised more often as a way of coping with moving weather fronts, for example. Gate reroutes can be put into effective use when a weather cell forces the closure of one or more gates. Rerouting can be a preferred option compared to extended holding or diversion to nearby airports. The reroute can be done while the aircraft are still in an upstream Center.

The traffic management supervisors and sector managers can also use the traffic prediction capability to determine staffing levels at each air traffic control unit. The appropriate staffing level can be determined for sectors that will be impacted and during which shift that congestion occurs.

5.4 Users or Involved Personnel

The users of TMA-MC will include:

- ATCSCC TMSs
- En Route TMCs
- En Route radar controllers
- Terminal area TMCs

Table 2. Users or Involved Personnel with TMA-MC

Users or Involved Personnel	Operations with TMA-MC
Traffic Management Specialist at ATSCSS	✓
Air Traffic Control Supervisor (ATCS)	✓
Supervisory Traffic Management Coordinator-in-Charge (STMCIC)	✓
Operations Supervisors (OS)	✓
Traffic Management Coordinator (TMC)	✓
En Route Radar Position – R controller	✓
En Route Radar Associate (RA) – D controller	✓
En Route Radar Coordinator (RC)	✓
En Route Radar Flight Data (FD) Position	✓
En Route Non Radar (NR) Position	✓
Terminal Radar Position – R controller	
Terminal Radar Associate (RA) – D controller	
Terminal Radar Coordinator (RC)	

Terminal Radar Flight Data (FD) Position	
Terminal Non Radar (NR) Position	
Tower Local Controller (LC)	
Tower Ground Controller (GC)	
Tower Associate	
Tower Traffic Management Coordinator	✓
Tower Flight Data Position	
Tower Clearance Delivery Position	
Flight Service Station Specialist (FSSS)	
Airline or Aircraft Flight Operations Center (AOC)	
Pilot or Flight Crew (FC)	

5.5 Support Strategy

To be determined

6. Operational Scenarios

Since the focus of TMA-MC research is on the Northeast corridor, and Philadelphia International Airport in particular, these scenarios are presented using facilities involved in the TMA-MC research: PHL, ZNY, ZDC, ZOB, ZBW, and the ATCSCC.

Operationally, for these scenarios, the PHL TMCs are designated the lead for using the TMA-MC's integrated traffic flow visualization tools to collaborate with the participating Centers to determine how best to resolve a PHL arrival traffic flow problem, where arrival demand exceeds airport capacity.

[p 6–11 Reference 11] There are eight typical arrival metering activities when using TMA-MC.

Setting Dynamic Airport Parameters

The PHL TMC enters current (and possibly future) airport runway configurations and associated AARs, as well as any other TRACON related scheduling constraints, into the TMA-MC scheduling window. Even though the current PHL runway configuration and AAR are displayed by TMA-MC, the PHL TMC verbally informs all the participating TMCs of the current runway configuration and AAR, as well as information about possible future changes. The TMCs (in all facilities) can observe the impact of configuration or AAR changes, especially for future runway or AAR changes, in the display of PHL load graphs and timelines that are common to all their TMA-MC displays.

Setting Dynamic En Route Parameters

The ZNY, ZDC, ZOB, and ZBW TMCs enter current (and future) restrictions (such as MIT restrictions) that could impact PHL arrivals and therefore impact PHL arrival demand. For example, ZNY may need to increase the MIT restrictions for PHL arrivals at the ZOB/ZNY boundary to account for significant IAD arrivals. The TMC making a change to PHL arrival restrictions in TMA-MC informs the TMCs in the other facilities. They could then observe the impact of the change in the TMA-MC load graphs and timelines.

TMA-MC handles non-dynamic en route information in system adaptation. TMA-MC's adaptation includes information about the nominal arrival delay controllability in each sector. Sectors with very limited delay controllability (because of their airspace structure e.g., narrow sectors, significant transitioning aircraft, and the presence of other aircraft not arriving at the primary airport of interest) may not be candidates to implement TBM and therefore any delay that TMA-MC estimates is needed may be handled by upstream sectors with adequate delay controllability or by internal airport departure delays coordinated by TMCs using TMA-MC tools (see Implementing Metering).

Seeing and Monitoring Real-Time PHL Load Graphs and Timelines

Using the PHL TRACON and en route parameters, adaptation data, and the real-time NAS flight plan and track data for PHL arrivals, TMA-MC computes the most efficient schedule for all PHL arrivals and displays the results in the load graphs and timelines. The load graphs and timelines are updated continuously to reflect all information about proposed and active PHL arrivals. The load graphs and timelines provide approximately two hours of lead time to the airport runway(s) threshold.

The TMCs in all the facilities see the same load graphs and timelines for PHL TRACON, primary runways (e.g., 27R/L, 35), and the primary PHL arrival meter fixes. This set of load graphs and timelines provides all facilities with a common view of the PHL arrival demand picture and is the basis for the collaborative decision making about whether or not to meter, as well as for other arrival traffic flow management decisions.

Using TMA-MC, the participating en route centers may also have additional load graphs and timelines displayed that reflect the PHL arrival picture oriented to their local needs. For example, ZOB may have a timeline associated with the PHL arrival traffic at the COFAX fix in the ZOB Imperial Sector near the boundary between ZOB and ZNY.

Deciding Collaboratively Whether to Begin Metering

As the lead for TMA-MC collaboration, the PHL TMCs monitor the TMA-MC load graphs and timelines to determine if and when metering might be necessary to keep the TRACON from becoming overloaded. The PHL TMCs may decide whether to initiate a telecon based on the magnitude of the average delay at PHL and the magnitude of delays for individual flights.

When the PHL TMCs decide that metering is necessary, based on their interpretation of the information provided by TMA-MC, they initiate a telecon with all the participating facilities to make a collaborative decision about metering. This telecon is normally initiated at least 90 to 120 minutes prior to a typical arrival rush so that if metering is initiated it can have the desired effect of smoothing out the rush with a minimum of holding.

During the telecon, the TMCs from the participating facilities determine whether or not they need to implement metering to manage the arrival demand to PHL during an upcoming arrival rush. Metering usually means having the sector controllers, handling the arrival traffic to PHL in ZNY, ZDC, ZOB and ZBW, start delaying the arrival aircraft to meet specific times at their metering control points. These metering control points are generally the arrival metering fixes and major center boundary crossing points, such as COFAX in ZOB. For each PHL arrival, TMA-MC, though the Host Computer System will display the specific metering time and the associated delay to meet that time to the appropriate sector controller in a TMA-MC metering list.

The PHL TMCs use the TMA-MC load graphs and timelines to explain the problem to the other participating TMCs and illustrate why they think metering needs to be implemented. The other participating TMCs see the same displays and may suggest other alternatives to address their facility-specific concerns.

While TMA-MC is designed to facilitate the use of TBM, it provides information that can help the TMCs decide whether TBM is the right option for some rushes. Depending on the information provided by TMA-MC, they may decide that a combination of TBM and MIT restrictions or just MIT restrictions is the right option. Feedback from TMCs and controllers about how they use TMC-MC to collaborate on arrival flow decisions will be gathered during the TMA-MC evaluation to help revise the TMA-MC concept of use.

The TMCs can use TMA-MC tools to assign delayed departure times for those internal departures destined to PHL so that they can merge smoothly into the metered PHL flow. Additional understanding of how TMA-MC can be used to help TMCs handle internal departure and Tower En Route Control (TEC) will be gained during the TMA-MC evaluations and from lessons learned by other facilities using these tools (in TMA-SC) for similar traffic, such as in ZLA and ZOA.

Informing ATCSCC of Decision to Meter

Because active metering will impose restrictions (meter fix times, MIT restrictions, or both) on multiple facilities, the ATCSCC may be required to review and approve the decision to meter. If the ATCSCC has access to the same TMA-MC displays, they could be a participant in a metering decision telecon. If the ATCSCC doesn't have access to the TMA-MC displays, then the PHL TMC contacts the ATCSCC after the decision to meter is made to review the reasons for that decision, using information from TMA-MC to support the need for metering and its impact on the facilities involved. TMA-MC provides the PHL TMC with quantitative data on the expected impact of metering, such as average delays for each facility.

Informing Others of Metering Decisions (and Changes)

The following facilities and individuals will be notified about the start time and expected end time of metering, as well as any changes to the flow management plan:

- Area Supervisors of the sectors that will actively meter
- TMCs at internal airports that will coordinate with PHL departures
- TMCs at Tower En Route Control airports that coordinate their PHL departures, or provide special MITs where appropriate.

Each Center's TMC will be responsible for notifying the individuals from, or coordinating with, their respective facilities.

The ATCSCC updates the Operational Information System (OIS) to reflect the PHL metering event, recording the start time, the expected end time, maximum delay, and average delay provided by TMA-MC.

Sometimes during a metering event, it becomes necessary to change some of the parameters that TMA-MC is using, such as when the runway configuration or the AAR is adjusted. When this is going to occur, the TMC who is initiating the change informs the TMCs in the other facilities that the TMA-MC scheduling information will be updated and that the sector metering lists will be "rippling", with the times and delays in the sector controller metering lists changing to account for the adjusted parameters. As it the current practices with TMA-SC, the TMCs will then let the appropriate Area Supervisors know that their sector controllers' metering lists will be rippling, and those Area Supervisors will let the affected controllers know when and why the rippling will occur. It is expected that, as in current TMA-SC use, every effort is made to ensure a stable schedule and to keep list ripples to a minimum.

Implementing Metering

Once the decision is made to implement metering, the following actions occur during the period when the facility is actively metering:

- The TMC at the affected facilities makes appropriate entries to enable the sector metering lists on the controllers' displays

- Sector controllers in those sectors that are actively metering follow their facility's standard operating procedures (SOP) for implementing TBM
- TMCs in internal TRACONs call their en route Center's TMC handling PHL arrivals to get a departure time for each PHL departure. The en route Center PHL TMC uses the TMA-MC tools to find an arrival slot in the metered flow and the slot's associated departure time. The internal airport departs the flight in an "x" minute window (e.g., 3 minutes) about the proposed departure slot.
- TMCs at the TEC TRACONs call for the appropriate facility (PHL, ZNY, ZDC, ZOB, or ZBW) to get a departure slot for a PHL TEC departure (or if they are using MITs for TECs, leave the TRACON controllers to achieve the required spacing.

Additional understanding of how TMA-MC can be used to help TMCs handle internal departures and TECs will be gained during the TMA-MC evaluations and from lessons learned reported by other facilities using these tools (in TMA-SC) for similar traffic, such as in ZLA and ZOA.

Ending Metering

Unless told otherwise, active metering ceases at the original end time identified when the facilities made the decision to meter. Obviously, if metering is still needed beyond that time, the participants are notified of the need for an extension. If metering is not needed as long as originally planned, the participants are notified of the revised end time and at that time the area supervisors/TMCs will inform the controllers that they no longer need to display their metering lists.

7. Summary of Impacts

7.1 Operational Impacts

TMA-MC impacts operations in several areas, due to its unique applications to enable a shift from MIT operations to TBM, and its requirements for more extensive coordination and information sharing than exists today in the PHL environment. As with most of the AATT decision support tools, TMA-MC provides advisory information to air traffic controllers with no impact on current air traffic control automation system functions. It is assumed that the operational version of TMA-MC will be sufficiently reliable to eliminate potential negative impacts to controller workload and safety that might result from TMA-MC anomalies.

7.2 Organizational Impacts

To be determined

7.3 Impacts during Development

As with TMA-SC, NASA will continue to work closely with the FAA during the development and test of TMA-MC. This involves the participation of FAA air traffic controllers in the development process during demonstration and test phases.

8. Analysis of the Proposed System

8.1 Summary of Advantages

The advantages described below refer to PHL; however, they generally apply to any terminal area that is fed by more than one Center.

[p 7 Reference 10] By sharing information across all five facilities, the TMA–MC design promises to improve situation awareness and facilitate strategic coordination of the PHL arrival plan. First, TMA–MC will provide to each TMU continuously-updated PHL arrival demand forecasts (up to 90-minute look-ahead) that are more accurate than anything currently available. It further will provide TMCs with continuous, unambiguous feedback regarding the development of the rush and the quality of the arrival plan. Second, this information is shared instantly throughout the TMA–MC network. This may facilitate a level of implicit coordination, as traffic managers at adjacent sites— even if not actively coordinating per se - will make decisions based on consistent information. There may be an attendant workload benefit, too, since better initial decisions should reduce the need to replan later. Third, the TMA–MC timeline and load graph displays will provide TMCs at each facility with a common picture of the status and plan, and common scheduling tools with which to evaluate options. It is envisioned that the timelines may become the context for discussion and negotiation between facilities. In this way, TMA–MC can facilitate simple, direct collaboration among the involved TMUs. Fourth, within each facility, the TMA–MC automation interface to the ARTCC infrastructure will enable TMCs to instantly distribute the coordinated plan to the appropriate sector controllers in his/her facility. This will facilitate real-time conformance actions that respond to the newly generated plan.

Better situation awareness may improve coordination inside PHL TRACON as well. The TRACON arrival airspace is divided into two sectors, north and south. During an arrival rush, each controller's "game plan" is affected by the volume and spacing of traffic inbound to the *opposing* sector. Presently, no information is available to either controller to indicate arrival demand to the opposing sector. As a result, controllers tend to adopt an overly conservative, and often more workload intensive, game plan for the rush. The availability of TMA–MC timelines to the arrival controllers in the TRACON may arm them with a more useful picture of north- and south-side arrival demand upon which to base their control actions.

<u>Delay Savings</u>

[p2-5 Reference 1] It is estimated that a deployment of TMA-MC will increase efficiencies in the Northeast airspace by reducing delays for the airports in Philadelphia and New York, and could also have positive impact on traffic throughout the NAS. For example, improved flow management decision-making for busy traffic sectors that funnel traffic to the Philadelphia and New York airports will significantly improve other hub operations (such as those at Chicago O'Hare Airport (ORD)) by reducing the need for unanticipated restrictions (e.g., large MIT pass-backs and internal Center ground stops).

Initial TMA-MC benefits studies for PHL (Reference 14) estimated modest benefits (delay reductions and associated user cost savings) when PHL traffic is fully metered. Modeling activities and benefits analysis have indicated that by the year 2005, implementation of the

TMA-MC concept will result in an annual delay savings of 105,000 minutes. The study also showed that the full potential of a TMA-MC capability applied to PHL was probably not possible without improving the flow of traffic into and out of N90 airports as PHL arrival flow management options are affected by N90 airport congestion. Recent observations of PHL arrival traffic in ZOB and ZNY show that Dulles International Airport (IAD) arrival flows may also impact TMA-MC performance. The enhancements derived from TMA-MC research in the Northeast Corridor will also provide valuable data for future deployments of TMA-MC to other sites outside the Northeast Corridor (e.g., St. Louis, Chicago).

A later study (Reference15) examined the direct operating cost savings of TMA-MC when deployed to 4 (the PHL Case), 8 and 12 sites. Cost savings of $4M, $32M, and $54M respectively were estimated. These estimates did not assign a value to passenger time saved. Furthermore, the benefit estimates were based on improved demand visualization and improved shut-off decisions, the first two of the potential benefit mechanisms described below.

Improved Shut-off Decisions

[p 5 Reference 14] Currently, without the use of TMA-MC, aircraft are allowed to flow into the PHL terminal area until the TRACON becomes overloaded. Miles-in-trail restrictions may be applied in an attempt to proactively manage the arrival situation, but shut-off is a common occurrence at PHL. Once the flow from the ARTCCs has been shut-off, it is difficult to accurately determine the appropriate time to resume the flow. In addition, delivery of flights out of holding patterns is inefficient.

TMA-MC can provide tools to support the shut-off and flow-resumption decisions. Considering the expected level of TMA-MC capability, the best method by which TMCs (or PHL controllers or supervisors) can use TMA-MC to determine when to resume the flow from the ARTCCs is the load graphs. A shut-off will occur when the number of aircraft in the TRACON airspace exceeds the TRACON capacity. Holding will be initiated. The load graphs will show that the demand at the threshold during the next 15 to 30 minutes exceeds the airport arrival capacity. This demand will include both the aircraft already within the TRACON, and the aircraft that are holding at the arrival fixes. As the flights already in the TRACON continue through the pattern to land, the demand shown on the load graphs in the next 15 to 20 minutes will reduce. The demand shown beyond 15 minutes will remain essentially constant while the aircraft outside the TRACON remain in a holding pattern.

Thus, the TMC (or specialist) should be watching the load graphs to see when the demand in the next 15 minutes meets or dips below the AAR. As soon as that point is reached, the flow should be resumed with appropriate miles-in-trail to keep the flow from overloading the TRACON again. TMA-MC tools can be used to determine these miles-in-trail restrictions.

Off-loading to Reliever Runway

Another potential benefit of TMA-MC at PHL is the ability to use TMA to identify the flights that can be off-loaded to a reliever runway. Due to the lower number of runways at PHL (3), creative and dynamic techniques are required to ‘squeeze-out’ as many arrival slots as possible. Runway 27R or 9R is used as the primary arrival runway. Generally, runway

17/35 is used for prop and turboprop arrivals. And when departure demand is low, runway 27L or 9L can also be used for a limited number of arrivals.

TMA-MC has the capability to identify the appropriate set of aircraft to be assigned to runway 17/35. TMA-MC can be adapted to recognize the specific aircraft types that can land on the shorter runway 17/35. The TMA runway allocation feature, which could operate effectively in the TMA-MC concept, automatically determines the best runway assignment plan to allocate workload and minimize delays.

By using the TMA-MC demand information, in combination with knowledge of departure demand, TMA can also support the identification of flights that can be off-loaded to the additional parallel runway that is generally used for departures.

However, this use of TMA-MC represents a change from current operations and it is difficult to assess the extent to which it can be used. Even though it is expected that this benefit mechanism will increase the potential benefits of the TMA-MC system, off-loading of *additional* flights to reliever runways was not modeled.

8.2 Summary of Disadvantages/Limitations

[p 6 Reference 10] The technical obstacles to TBM at Philadelphia are largely generic to all of the major airports in the Northeast Corridor. Broadly categorized, they include obstacles to coordination; limited ability to absorb delay in the arrival sectors; uncertainty in the estimated times of departure of short-haul flights bound for the adapted airport; and the potentially significant operations and workload implications of incorporating a new control paradigm, TBM. Each is discussed in turn the subsections that follow.

Inadequate Infrastructure for Coordination

The NAS infrastructure is not set up to support inter-facility coordination. Inaccurate or inaccessible information, poor feedback mechanisms, and cumbersome communication protocols contribute to an environment of "protectionism" in most facilities that is not conducive to productive collaboration. NASA researchers are working in cooperation with researchers from MITRE/CAASD to develop system requirements for TMA–MC that are expected to raise the level of common situation awareness among and within the facilities to facilitate more productive planning of arrival rush operations.

As discussed, four different Centers and six different TRACONs handle PHL arrival traffic. PHL TRACON, in consultation with ZNY, ZDC and the ATCSCC, has responsibility for establishing the arrival plan, setting the necessary restrictions at the arrival fixes, and coordinating them with its adjacent facilities, ZNY and ZDC. Those facilities, in turn, pass back restrictions to their upstream facilities (e.g., ZOB, ZBW) based on the restrictions PHL has imposed. However, once the plan is established and the arrival rush is underway, there is little feedback available to TMCs with which to monitor the development of the rush or the adequacy of the plan. As a result, the local and regional situation awareness of the TMCs regarding the performance of the arrival operation tends to erode as the rush progresses. Furthermore, even if good situation awareness could be maintained, the time and workload required to negotiate and communicate a coordinated multi-facility response to a developing over- or under-capacity situation is generally too great. Therefore, amendments to the arrival plan tend to be reactionary, over compensatory, and late. In the worst case, traffic demand builds until the north and/or south arrival controller(s) at PHL TRACON must call for immediate airborne holding at the arrival fix. This action, referred to as “no-notice holding” or (in less polite conversation) as “slamming the door,” causes considerable stress and workload in the upstream sector, and the upheaval can ripple quickly upstream through adjacent sectors and facilities, contributing to frustration and misplaced blame.

Limited “Delayability”

To implement an arrival metering plan, TMCs depend on Center sector controllers to delay arrival aircraft such that each aircraft crosses a pre-defined metering reference point at its scheduled time of arrival. Controllers typically conform to metering delays by assigning vectors, speed restrictions and/or early descent clearances. The amount of delay that can be absorbed in a sector is a direct function of the time and space a controller has in which to execute these tactics. “Delayability” is defined as the aggregate delay that all controllers along an arrival path can be expected to absorb on a per-aircraft basis.

Delayability along the arrival streams to PHL is significantly less than that found at TMA–SC sites outside the Northeast corridor. It is limited by two principal factors: the fragmented control of the arrival flows, and the large segment of arrival traffic that enters PHL TRACON from its adjacent approach control facilities. Both factors are explained next.

Fragmented control is best explained with an example. At Fort Worth Center, arrival flights are metered through two sectors, spanning as much as 250 nm, prior to entering the DFW TRACON. At Philadelphia, depending on the arrival route, arrival flights descend through as many as four sectors over the same distance. This fragmentation of control limits each controller’s opportunity to absorb delay, because s/he has control over a flight for only a short time, and because the small sector dimensions constrain his/her room to vector. Therefore, an aircraft’s total delay must be absorbed in piecemeal fashion, in small increments by several controllers over several sectors in series.

This dynamic became apparent in simulation, and it has driven two design modifications. First, the amount of delay each sector is expected to absorb has been revised downward. Second, the metering horizon has been expanded well beyond the original expectation. Expanding the horizon has revealed an additional benefit, as sectors tend to be larger further from PHL, enabling disproportionately more delay to be absorbed there.

The second factor affecting delayability is the large component of PHL arrival traffic which comes to PHL TRACON from an adjacent approach control facility (e.g., Atlantic City TRACON, Reading TRACON). Roughly 40% of all PHL arrivals, mostly turboprops, are routed this way. Once these aircraft descend out of Center airspace and into approach control, their arrival times are no longer influenced by Center actions. Thus, TMA loses its only means by which to control these aircraft to their metering times. As a result, the delay assigned to each of these aircraft must be absorbed prior to this transition. To compensate, metering of these aircraft must be initiated further upstream (i.e., the metering horizon must be expanded).

Workload

Until it is shown that use of TMA–MC and TBM for Philadelphia arrivals reduces workload in the arrival sectors and in the TMUs, it will be difficult to earn the confidence and acceptance of air traffic personnel. This is a significant challenge, as just one of these facilities (Boston Center) has experience with TBM. It is important, however, to distinguish between the temporary workload associated with introducing metering into the operational environment (i.e., training and refinement of skills and procedures) and the steady-state workload associated with a mature TBM operation using TMA–MC.

The temporary (or “transitional”) workload may be significant. Spacing aircraft by time as opposed to distance requires a different mindset and approach. The control problem changes from a pairwise, spatial separation task to a one-by-one, temporal spacing task. The transition to this new paradigm will exact a workload premium on the controllers over the short term. Their training and initial experience will benefit from the lessons learned at TMA–SC facilities, some of which also have had to transition from miles-in-trail spacing to TBM.

Clearly, there will be a workload burden incurred as air traffic personnel climb the learning curve. In the end, however, the relevant workload indicator— the one upon which TMA–MC will be measured— is whether controller workload will be sustainable in a mature, TBM operation under TMA–MC.

This is still an open question. For example, consider that controllers will still need to ensure spatial separation, as a first priority, for all traffic including their unmetered (parallel and/or crossing) streams. In some cases, metered aircraft may be in-trail with unmetered aircraft. A controller’s ability to accomplish in-trail spacing and TBM concurrently on multiple aircraft sharing a common stream is an important human factors consideration that has not been encountered in previous TMA research. Further study of this issue is planned as part of the research program.

A primary benefit of arrival metering with TMA–MC is expected to be a more steady workload profile. In operational use of TMA–SC at Fort Worth Center, researchers observed a beneficial redistribution of controller workload. Peak workload subsided and was shifted to less demanding times. The overall result was a more consistent and less stressful operation. With the anticipated reductions in airborne holding and improvements in the regularity of the arrival flows, TMA–MC facilities are expected to realize a similar stabilization in controller workload.

8.3 Alternatives and Tradeoffs Considered

Five operational concepts for TMA-MC were originally identified by NASA Ames (References 16 and 17). Through further analyses, these were narrowed to three concepts which in turn were reduced to the single concept described in this OCD.

9. Notes

Acronyms and Abbreviations

AAR	Airport Acceptance Rate
AATT	Advanced Air Transportation Technologies
AIAA	American Institute of Aeronautics and Astronautics
ALB	Albany Airport
AOZ	FAA Free Flight Program Office
ARC	Ames Research Center
ARTCC	Air Route Traffic Control Center
ARTS	Automated Radar Terminal System
ATCSCC	Air Traffic Control Systems Command Center
ATL	Atlanta-Hartsfield Airport
ATM	Air Traffic Management
BDL	Bradley Airport
BOS	Boston Logan International Airport
BTV	Burlington Airport
BUF	Buffalo Airport
BWI	Baltimore Washington International Airport
CAASD	Center for Advanced Aviation System Development
CDRL	Contract Deliverable Requirements List
CLE	Cleveland Hopkins Airport
CLT	Charlotte Airport
CM	Communications Manager
CMH	Columbus Airport
CTAS	Center TRACON Automation System
CVG	Cincinnati Airport
DAY	Dayton Airport
DCA	Reagan Washington National Airport
DFW	Dallas Fort Worth International Airport
DP	Dynamic Planner
DS	Data Server
DSC	Downstream Sector
DSR	Display System Replacement
DST	Decision Support Tool
DTW	Detroit-Wayne International Airport
EDAR	ETMS Data Archive Router
ETA	Estimated Time of Arrival
ETMS	Enhanced Traffic Management System
EWR	Newark International Airport
FAA	Federal Aviation Administration
FAF	Final Approach Fix
FAST	Final Approach Spacing Tool
FC	Flight Crew
FCFS	First Come First Served
FD	Flight Data Position
FFP1	Free Flight Phase 1
FFP2	Free Flight Phase 2
FSSS	Flight Service Station Specialist

GC	Ground Control Position
GUI	Graphical User Interface
HAR	Harrisburg
HCS	Host Computer System
HID	Host Interface Device
HNL	HID/NAS LAN
IAD	Dulles International Airport
IEEE	Institute of Electrical and Electronic Engineers
ILG	Wilmington Airport
ISM	Input Source Manager
ISP	Islip (NY) Airport
JFK	John F. Kennedy International Airport
LAN	Local Area Network
LC	Local Control
LGA	Laguardia International Airport
MHT	Manchester Airport
MIT	Miles-In-Trail
MRP	Metering Reference Point
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NR	Non Radar
NXX	Navy Willow Grove Airport
OCD	Operational Concept Description
OIS	Operational Information System
ORD	O'Hare International Airport
PARR	Problem Analysis and Resolution and Ranking
PGUI	Planview Graphical User Interface
PHL	Philadelphia International Airport
PIT	Pittsburg Airport
PNE	North Philadelphia Airport
PTW	Pottstown Fix
PVD	Providence Airport
RA	Route Analyzer
RDU	Raleigh/Durham Airport
ROC	Rochester Airport
RTCA	RTCA, Inc. (formerly Radio Technical Commission for Aeronautics)
SOP	Standard Operating Procedure
STA	Scheduled Time of Arrival
SYR	Syracuse Airport
TEC	Tower En Route Control
TBM	Time Based Metering
TFM	Traffic Flow Management
TGUI	Timeline Graphical User Interface
TMA	Traffic Management Advisor
TMA-MC	TMA Multi Center
TMA-SC	TMA Single Center
TMC	Traffic Management Coordinator
TMIC	Traffic Manager in Charge
TMS	Traffic Management Specialist
TMU	Traffic Management Unit
TRACON	Terminal Radar Control Facility

TRL	Technology Readiness Level
TS	Trajectory Synthesizer
TTN	Trenton Airport
US	United States
USC	Upstream Center
VCN	Cedar Lake Fix
VOR	Very High Frequency Omni Range
WAN	Wide Area Network
YOW	Ottawa
YUL	Montreal
YYZ	Toronto Airport
ZBW	Boston Center
ZDC	Washington Center
ZDV	Denver Center
ZFW	Fort Worth Center
ZLA	Los Angeles Center
ZMA	Miami Center
ZMP	Minneapolis Center
ZNY	New York Center
ZOA	Oakland Center
ZOB	Cleveland Center
ZTL	Atlanta Center